

Cryostat Issues for SPS Crab Cavity Run: Envelopes and Interfaces

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Acknowledgments

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SPS Run: Overview of Constraints on Cryostat design

- **Cryo module must contain 2 cavities**
- **Cryomodule must be out of beam line when cavities not under test**
 - Remote control of movement essential
 - Module to be moved while cold and full of LHe
- **Alignment and positioning:**
 - Accurate positioning wrt the closed orbit beam is essential
 - Question: Is active alignment within the cryostat required/feasible?
- **Cryo module should be exchangeable in an SPS technical stop**
 - Technical stop = 3 days => common envelopes and common interfaces
- **Foresee both horizontal and vertical crabbing could be tested:**
 - Possibility of more than one cryostat tested in SPS Run
 - Designs must have common connection interfaces (type + position)

Infrastructure constraints on location

- **Cryogenics: Can't guarantee 24/7 cryo operation in SPS**
 - Cryo module: must be able to cycle it out of the beam line
 - Space required for “out of beam position”
 - Horizontal move (standard) => SPS alcove (not possible in tunnel)
 - Vertical move: Very very challenging, space/clearance an issue
- **Interfaces**
 - Rigid connection between tetrode and cryomodule
 - Rigid connection between cryo 2K expansion box and cryomodule
- **RF-Power and LLRF**
 - Tetrode+ circulator as close as possible to cryomodule
 - **Space required => location restricted to an alcove**

Infrastructure constraints on location

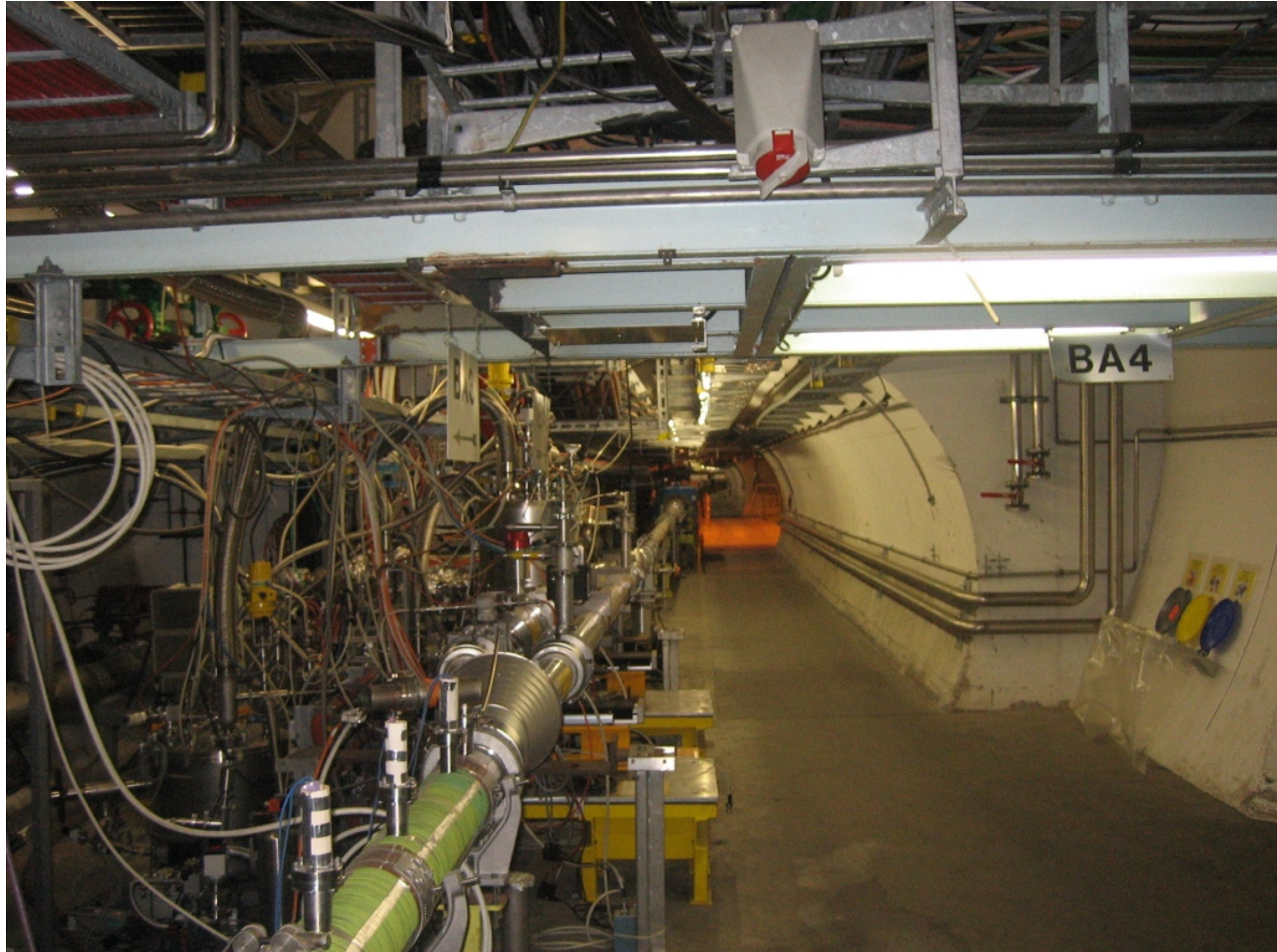
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**SPS: Cryo module location needs space for Y-chamber and RF power
=> location must be in an SPS alcove (or similar)**

SPS: Space in the tunnel

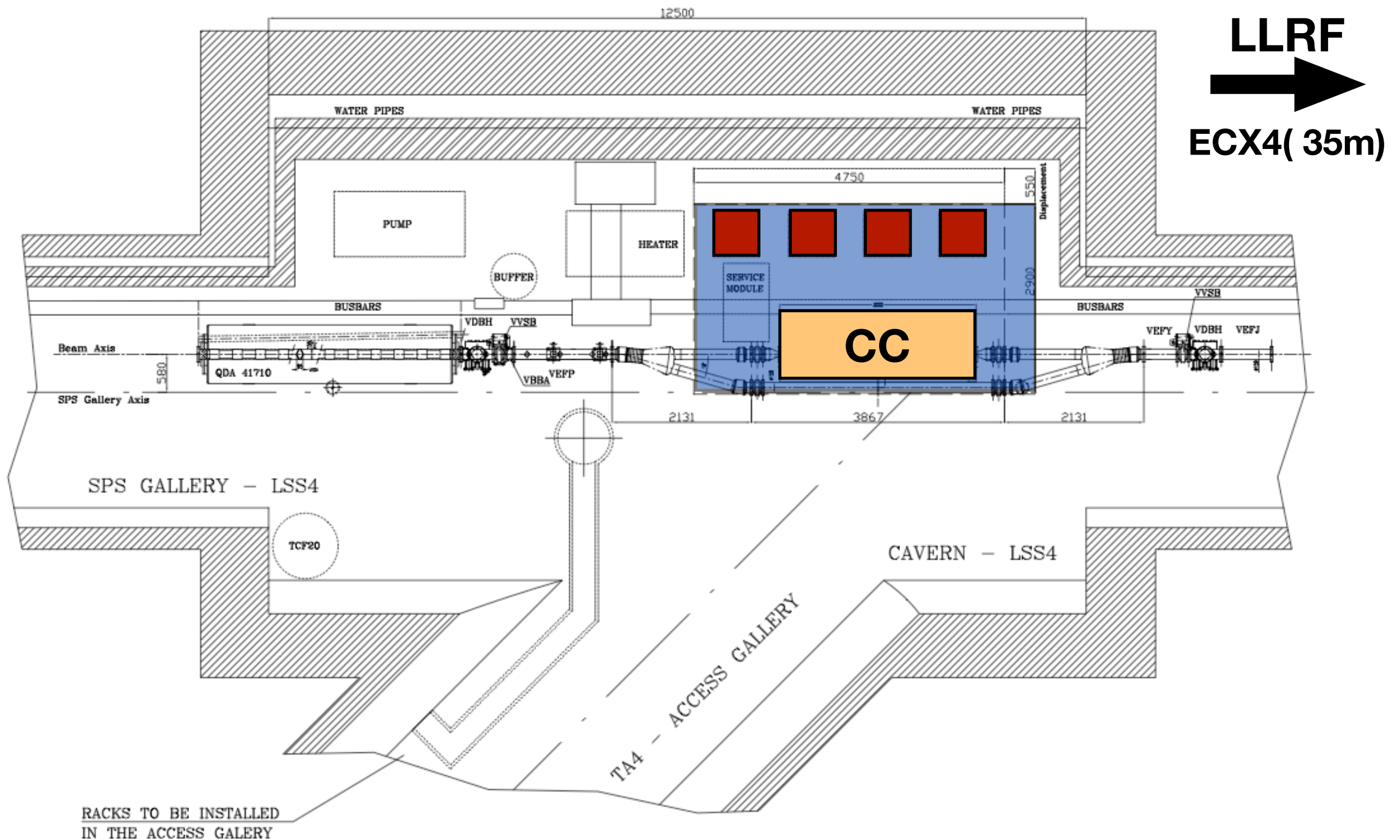


SPS: Space in the Alcove



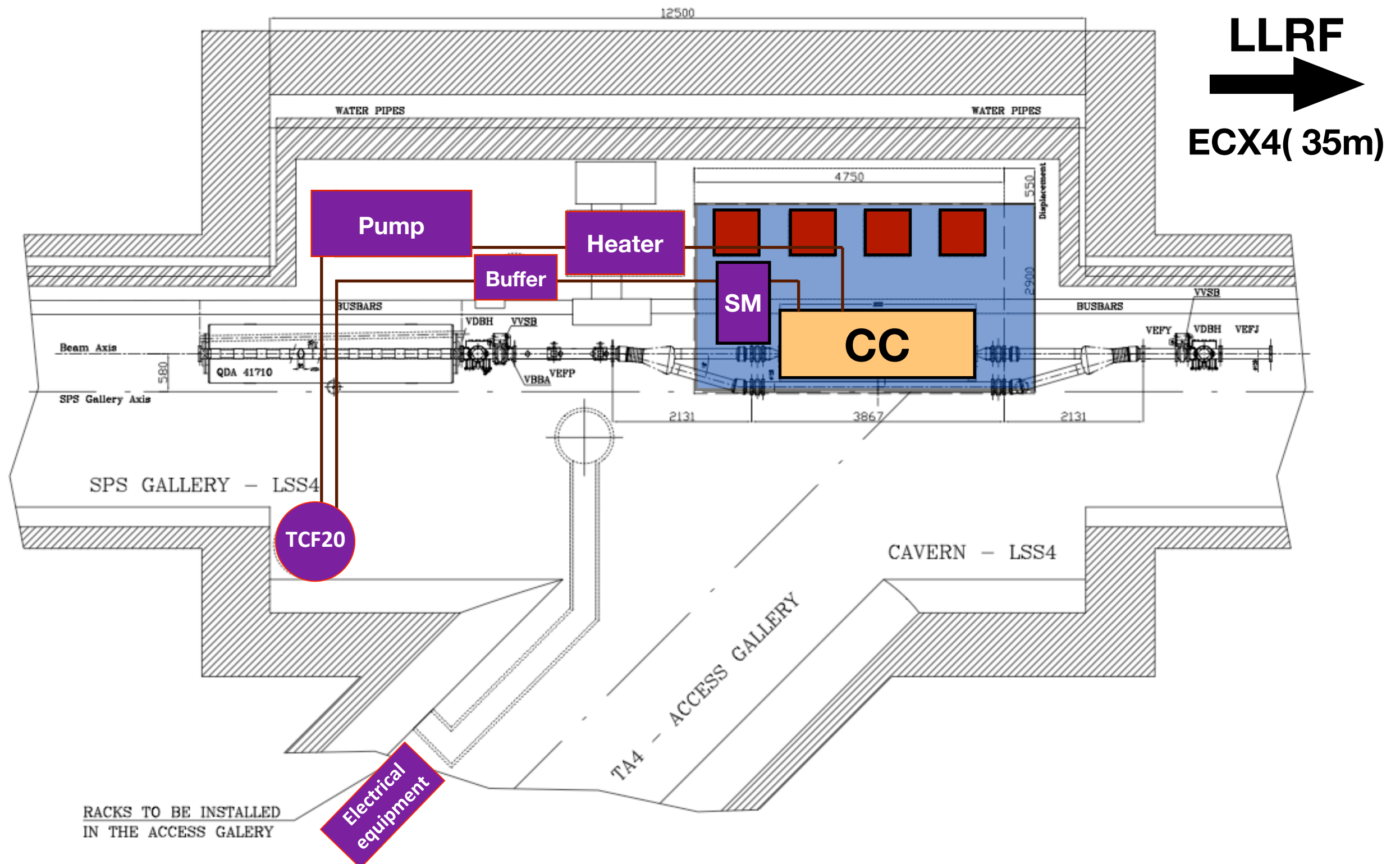
SPS location: LSS4

SPS: LSS4 alcove of BA4 is the only location that is feasible /available



SPS location: LSS4

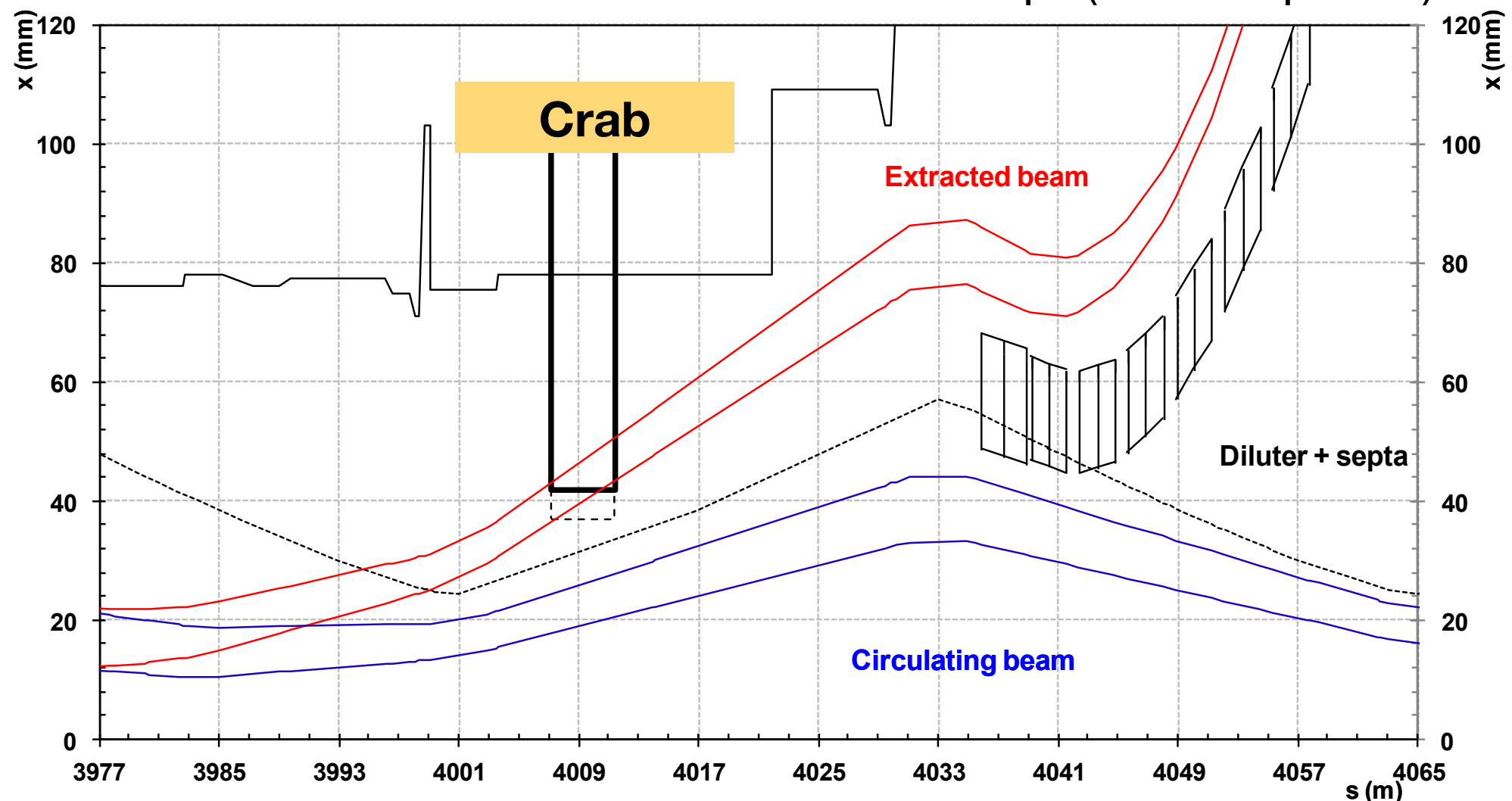
SPS: LSS4 alcove of BA4 is the only location that is feasible /available



Issues with the SPS LSS4 Location

- **SPS Extraction bump prohibits CC in beam when filling LHC**
- CCs in beam: Blocks LHC filling. Aperture bottleneck for normal SPS operation
=> **Y-Chamber needed so cavities can be bypassed when not under test**

SPS LSS4: LHC Extraction bump (Q20 optics)

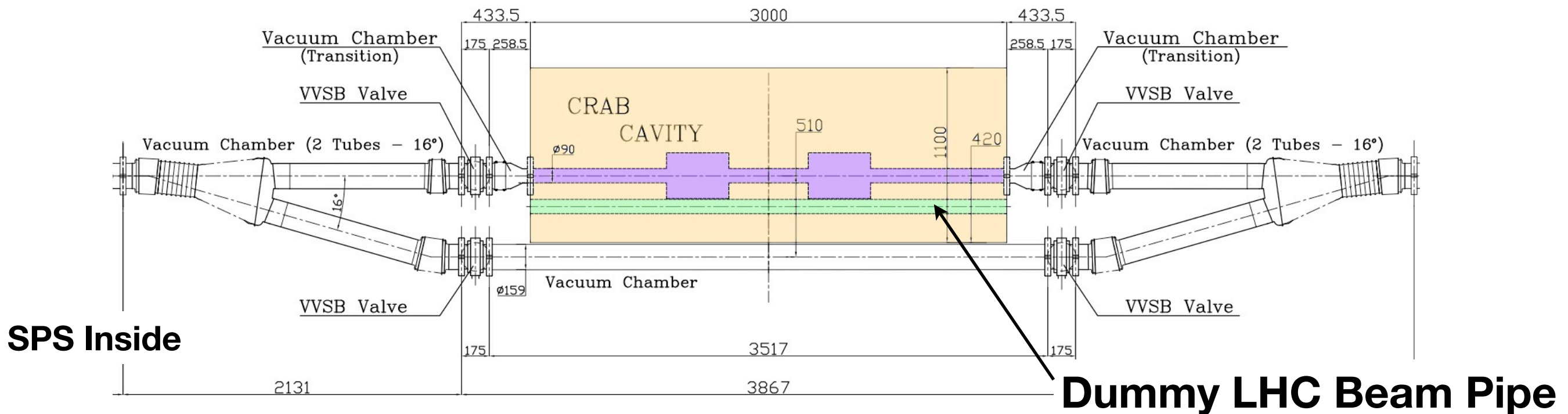


Location is not ideal: Aperture bottleneck + must interlock on CC + LHC filling

Movement of Crab cavities in/out of beamline

SPS operation must be independent of crab cavity operational availability
=> Crab Cavity cryomodule switchable from in-beam to out-of-beam position

SPS Outside

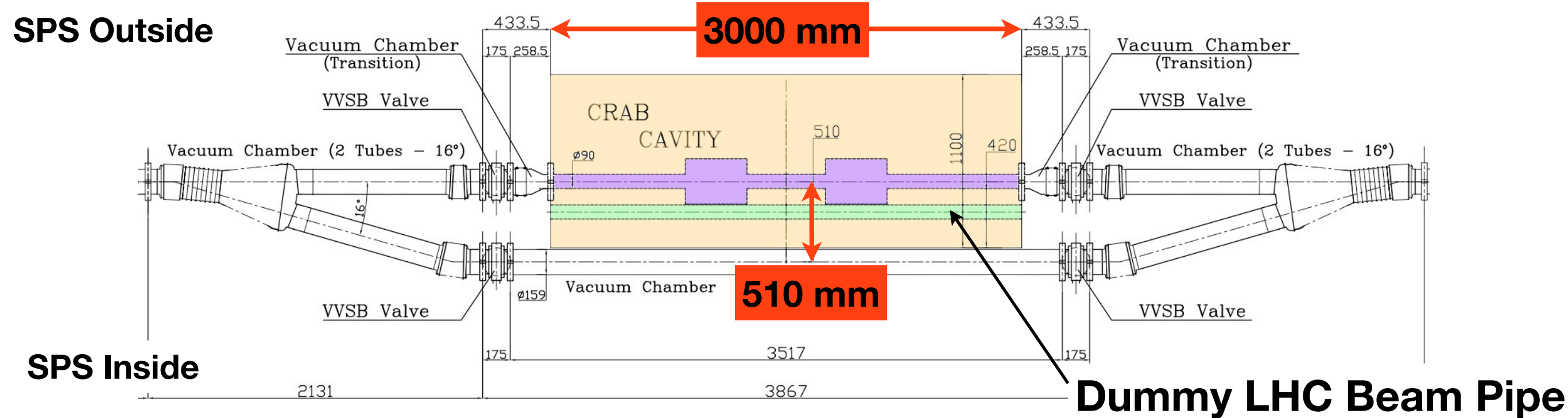


Movement of Crab cavities in/out of beamline

SPS Outside

- **Y-chamber movement: reproducible 51cm movement in < 30min**
 - Must be remote controlled (ie no access required) and take
 - Safety incorporated into support structure design
 - **Mechanical movement with helium vessels, cryo-lines etc at 2K**

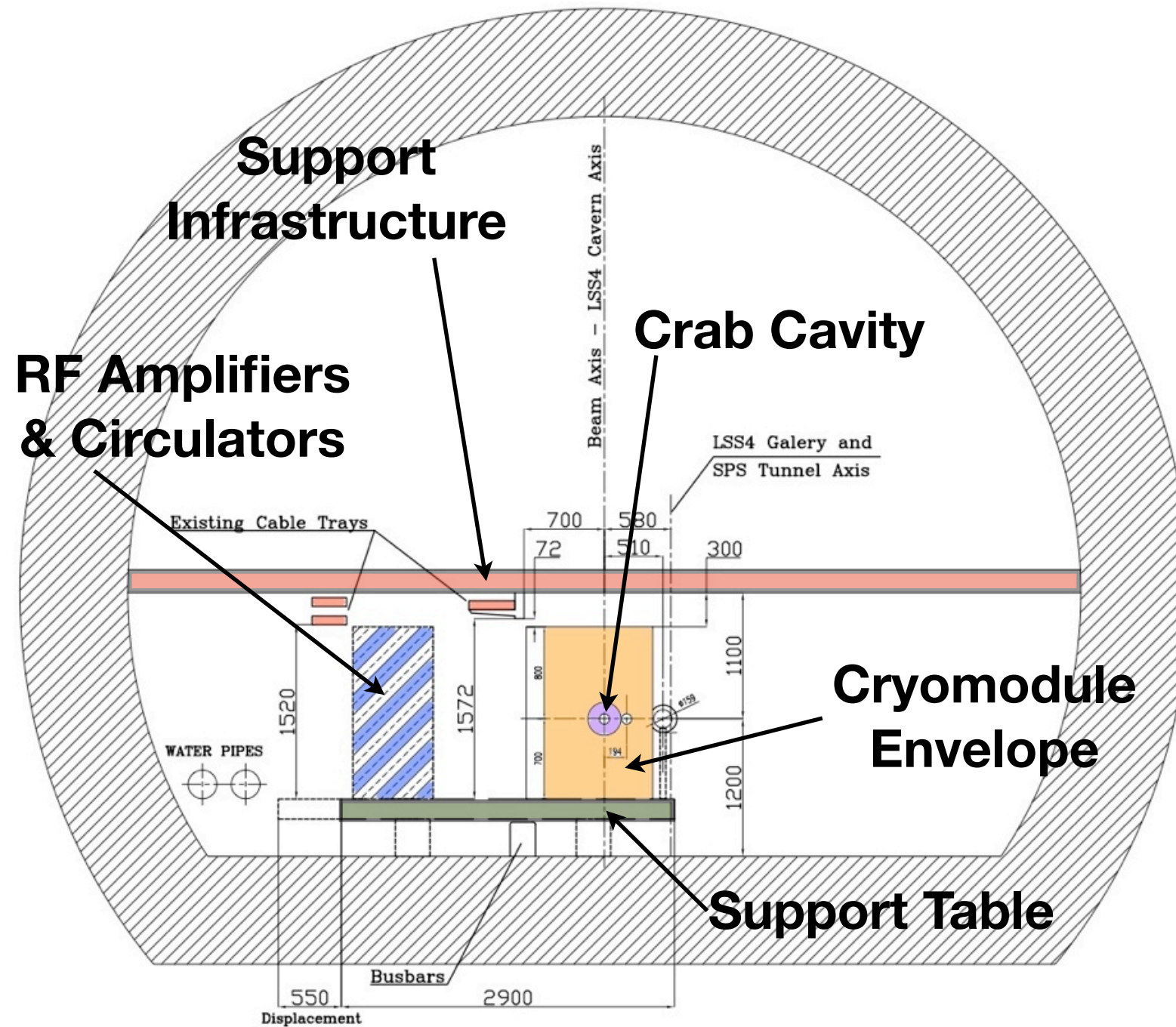
Crab Cavity Integration envelope



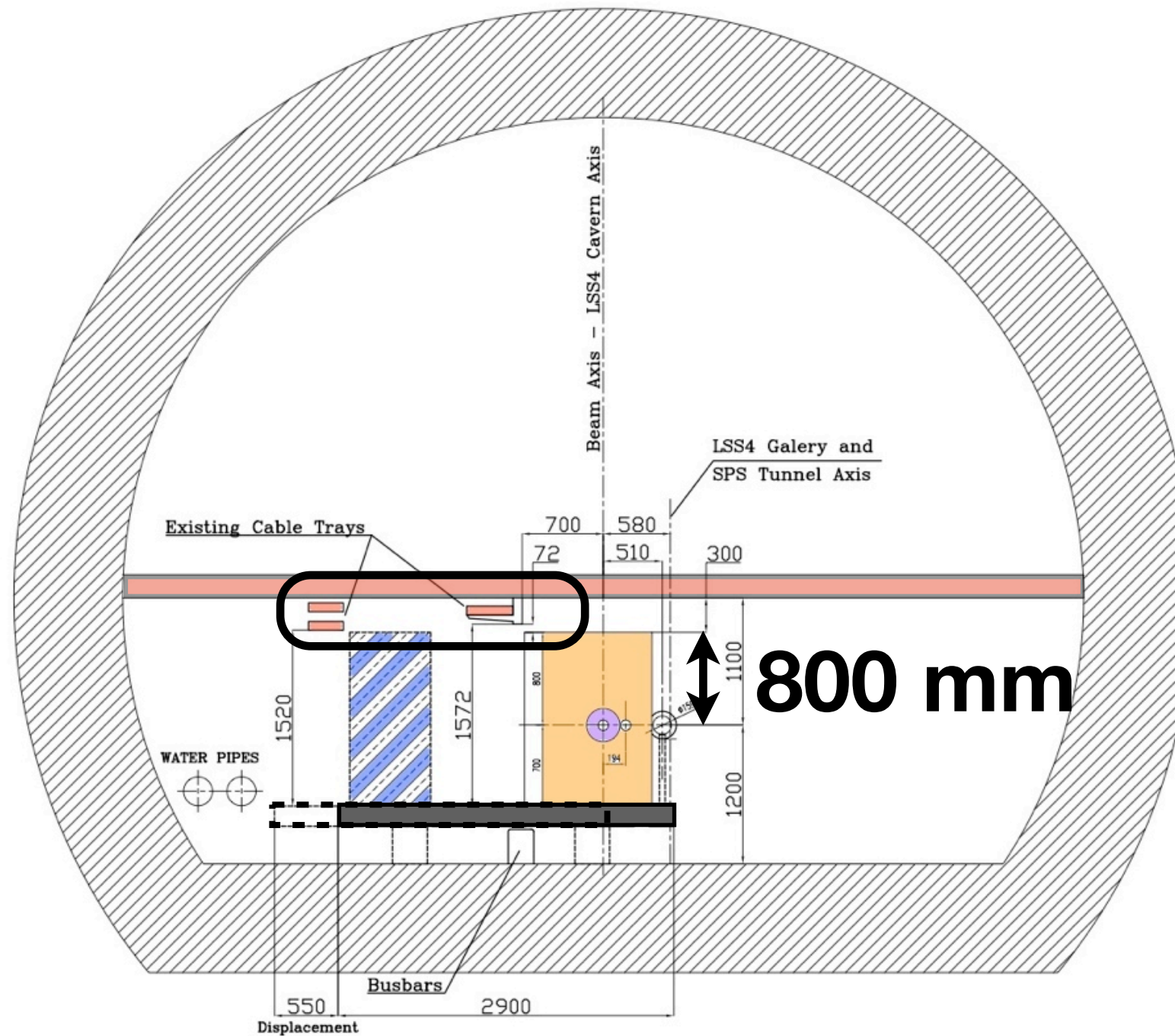
Description	Distance [mm]
Envelope z-length	3000
Cavity axis to inner edge of Envelope volume	420
Cavity axis to outer edge of Envelope volume	680*
Cavity axis to bottom of Envelope volume (top of support table)	700*
Cavity axis to top of Envelope volume	800
Cavity axis to SPS floor	1200
Cavity axis to By-pass axis	510
Diameter of bypass beam line	159
Diameter of cavity aperture	84
Dummy beam pipe outer diameter (HL-LHC BP in Q4-D2 region)	~100
Cavity axis to dummy beam pipe axis	194

* = possible to increase

Crab Cavity Integration envelope



Crab Cavity Integration envelope

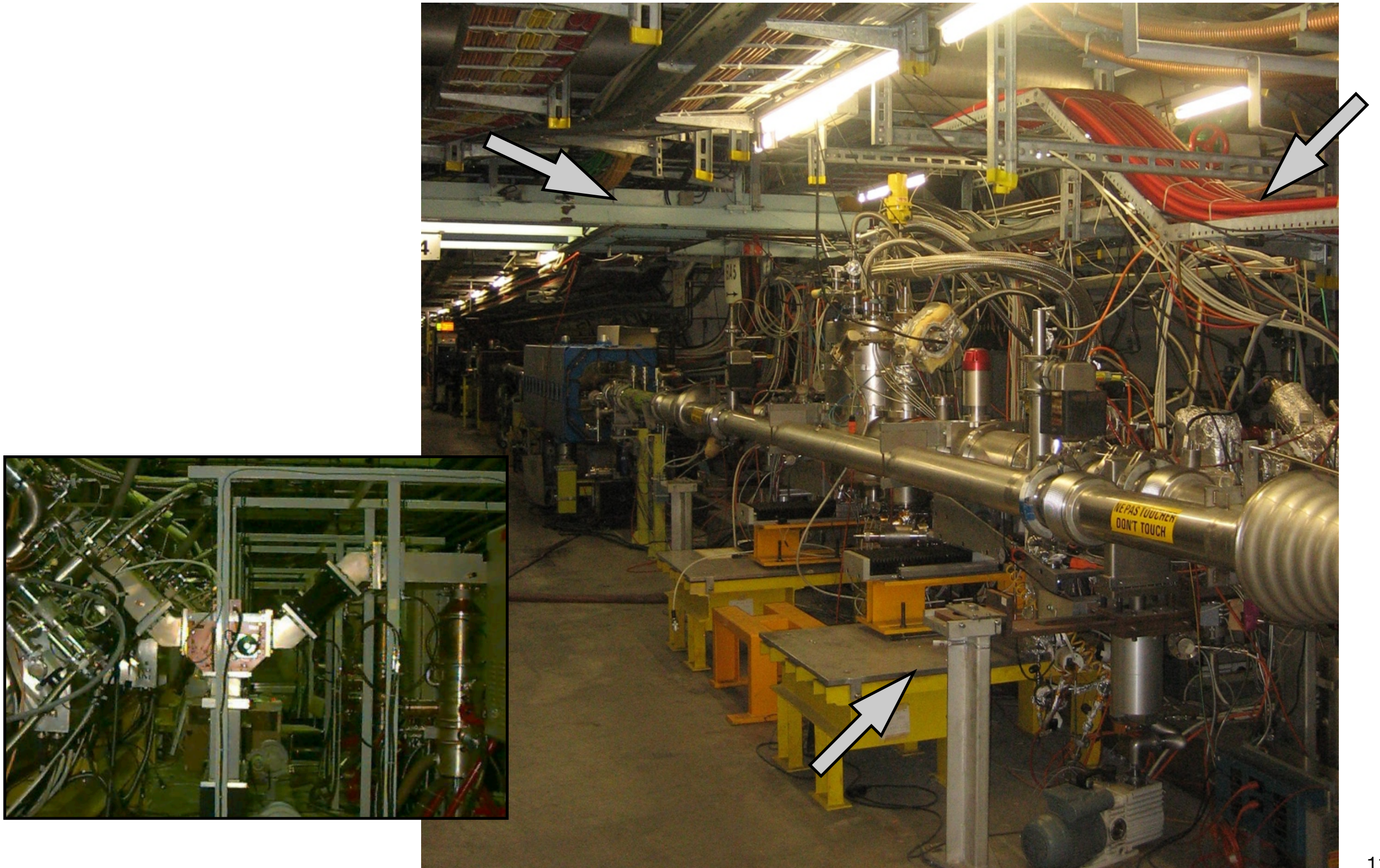


External connections need to be inside in envelope as have to respect table movement constraints => integration interfaces not a lot of space

Space in LSS4 - Physical Obstacles

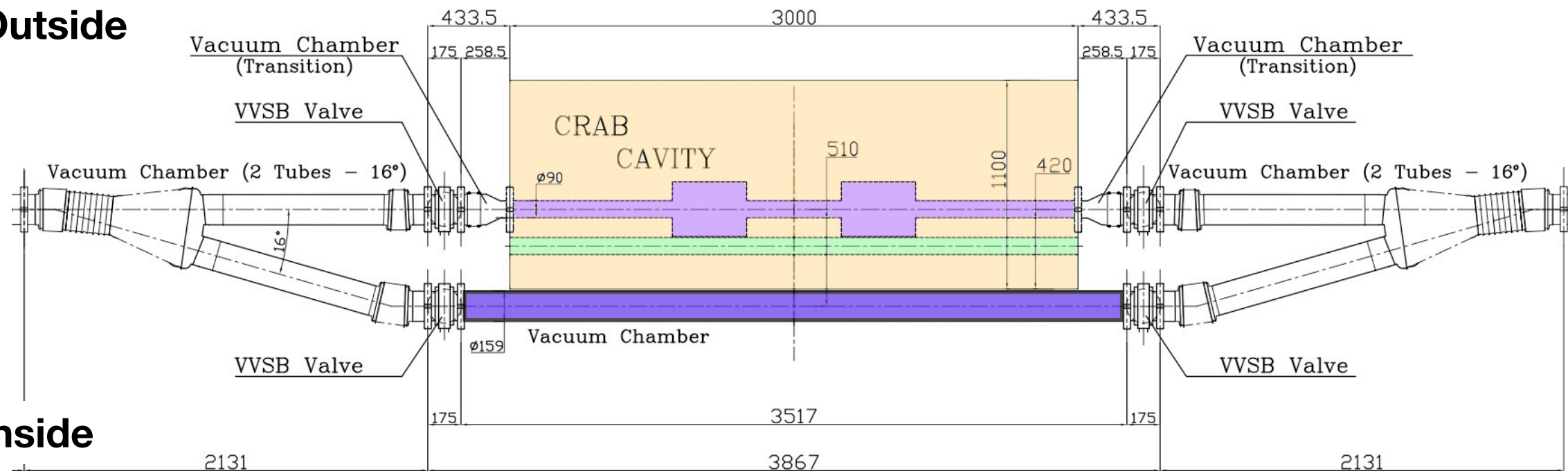


Space in LSS4 - Physical Obstacles



Integration Envelope Questions

SPS Outside

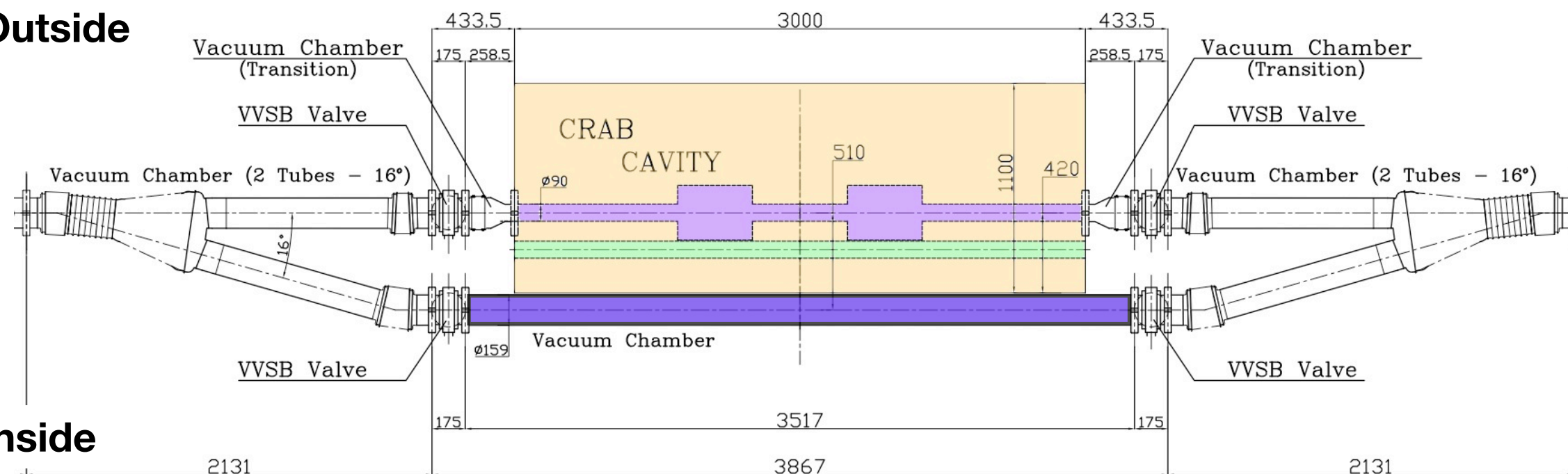


SPS Inside

- **Dummy Beam Pipe: CC Axis-to-Dummy BP axis distance = 194 mm**
 - Can be at any location (horizontal, vertical etc) wrt CC axis
 - Exception: UK-4Rod has FPC connection to CC on horizon
 - **Question 1: Can we move location of dummy Beam pipe?**
=> we gain space between CC and by-pass, makes things easier.

Integration Envelope Questions

SPS Outside



SPS Inside

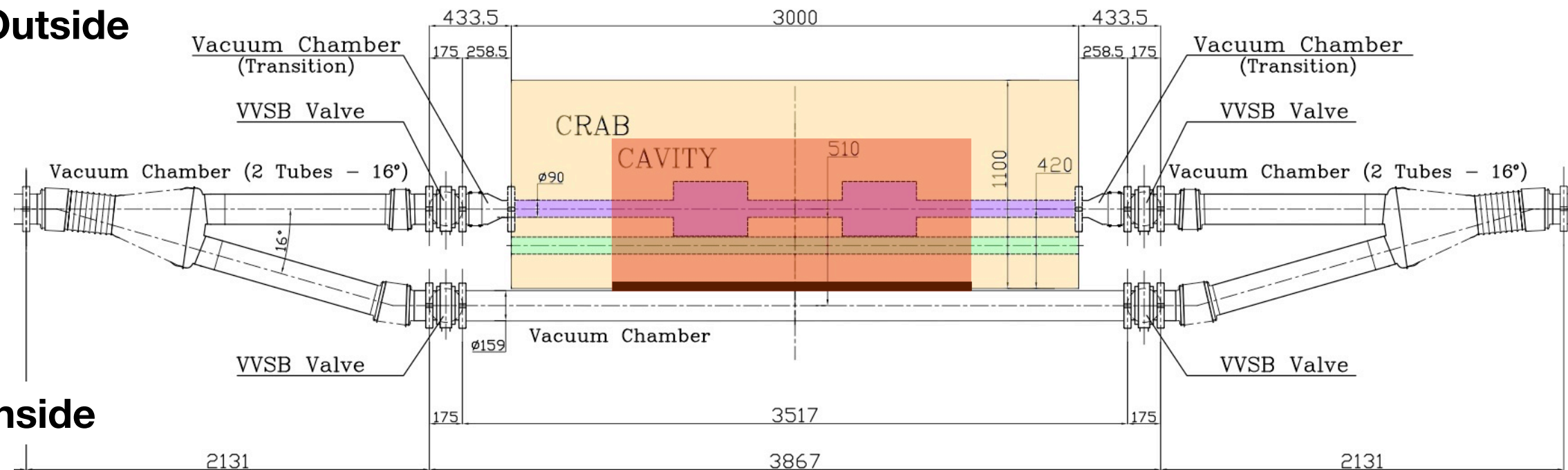
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=> we gain space between CC and by-pass, makes things easier.

Question 2: Can distance from CC axis to the inside edge of envelope be reduced from 420mm to 255 mm?

- **If so we can use existing Y-chamber**

Integration Envelope Issues

SPS Outside

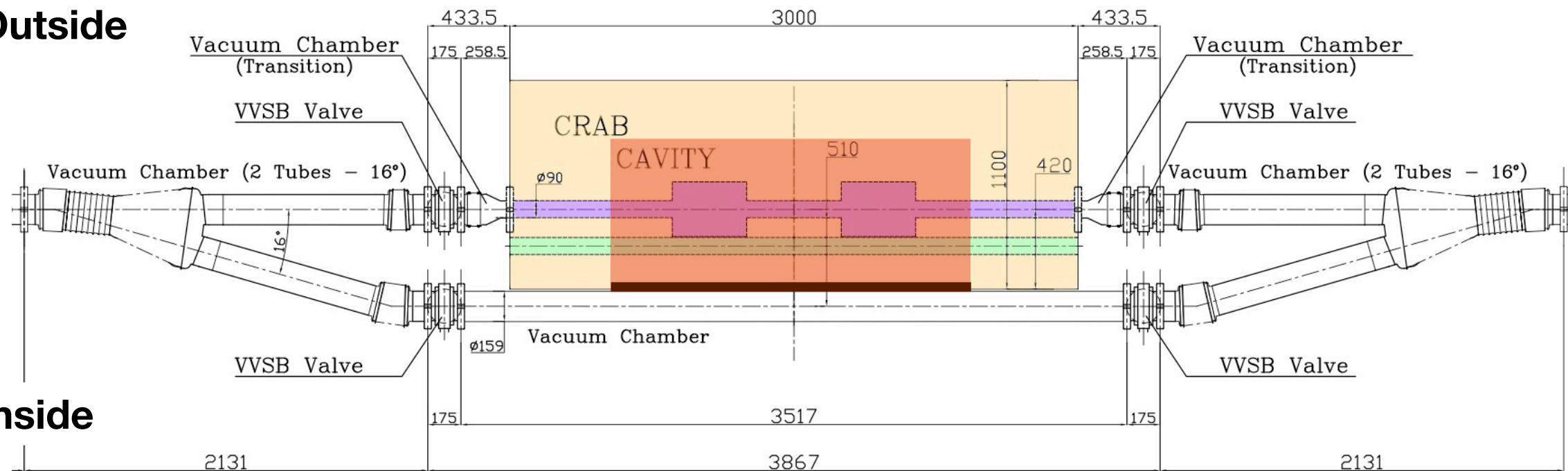


SPS Inside

- **CC Envelope: Physical envelope of space available**
 - Includes cryo module and connections (up to integration interfaces)
 - **Connections from all sides except inside face**

Integration Envelope Issues

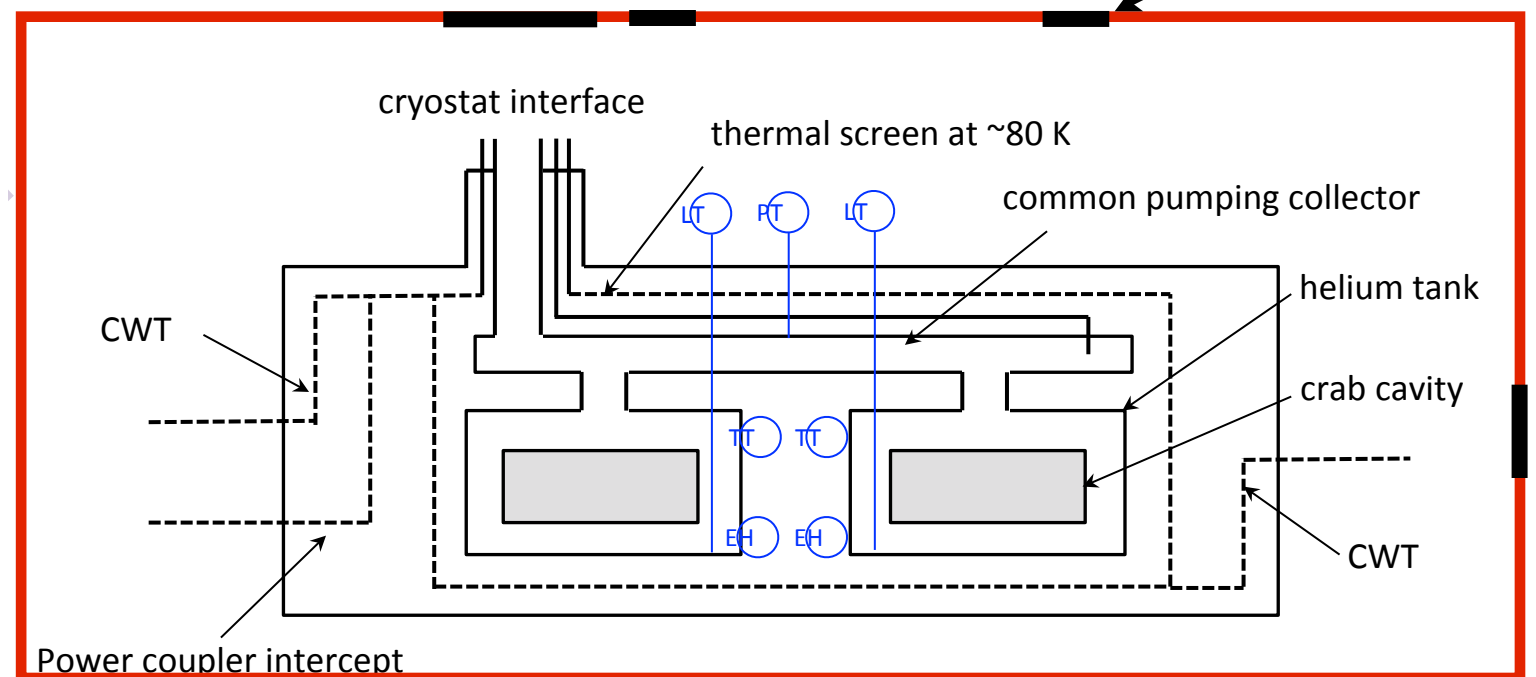
SPS Outside



SPS Inside

- **CC Envelope: Physical envelope of space available**
 - Includes cryo module and connections (up to integration interfaces)
 - **Connections from all sides except inside face**
- Integration interfaces at envelope need to be clearly defined
 - Must take connections into account
 - Input to specifications

Integration interfaces



Alignment Tolerances

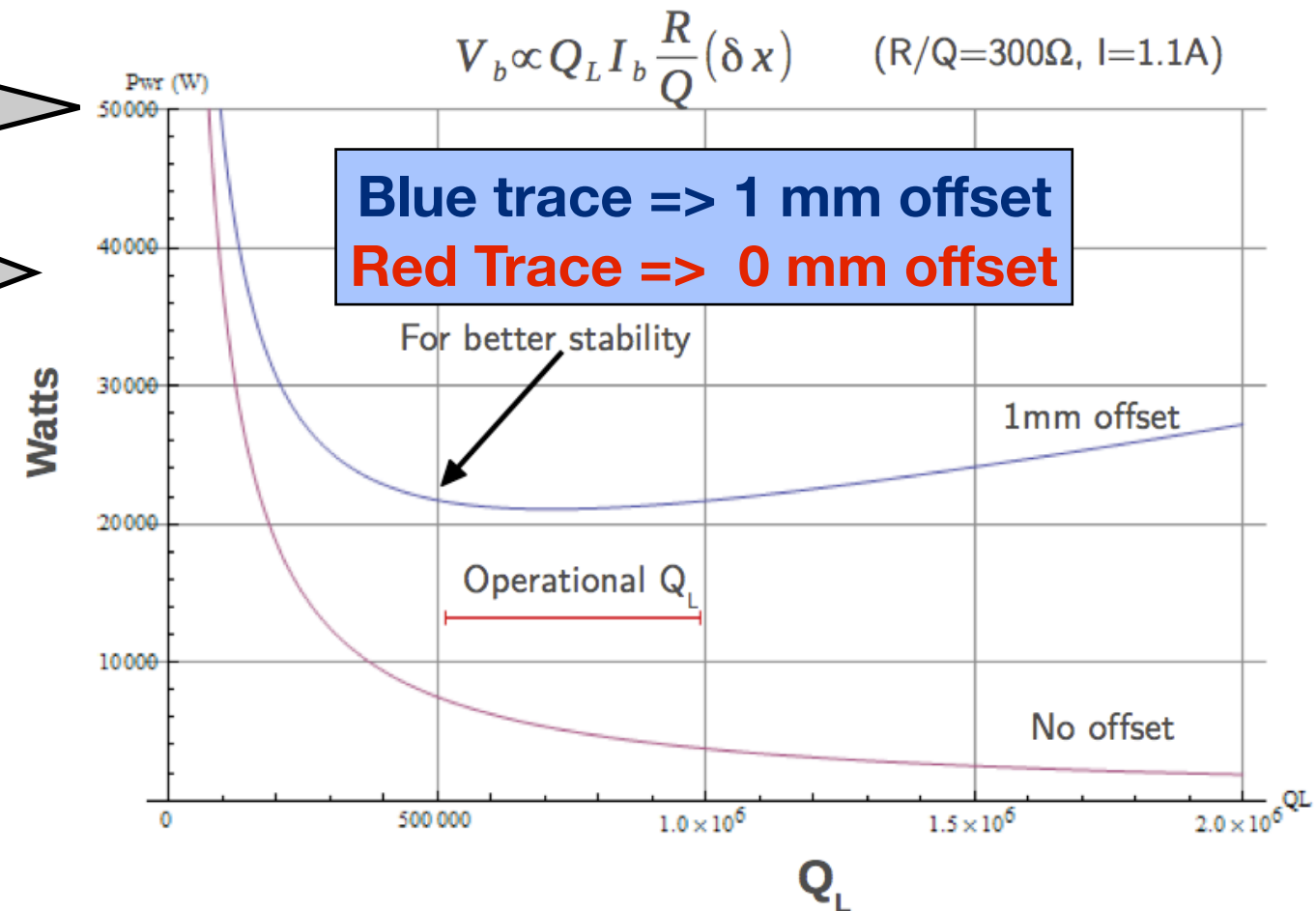
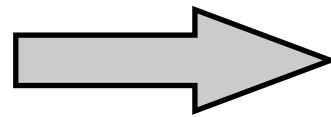
- Based on modeling Crab Cavities with multipoles up to octupole order
- **Transverse misalignment tolerances [TMT]**
 - TMT defined as a 1 sigma reduction of dynamic aperture.
 - **TMT = 0.7 mm for each cavity**
 - Applies to both planes: different crossing schemes for IR1 & IR5
- **Tilt of the cavity wrt longitudinal cryostat axis < 1 mrad**
 - Based on luminosity loss, closed orbit deformation, tune modulation
- **Transverse rotation of individual cavities inside cryostat < 5 mrad (~0.3 deg)**
 - Based on effects of parasitic crossing angle in the non-crossing plane
- Assume
 - electro-magnetic centre axis of cavity = geometrical longitudinal axis of cavity
 - = longitudinal cryostat axis
 - = geometric center of the beampipe

Positioning of Cryomodule

- RF amplifier TX power vs. Q_{EXT} : (400 MHz - 50 kW SPS Tetrode)

Acceptable transverse offset of beam wrt cavity of O(1mm)

50 kW →

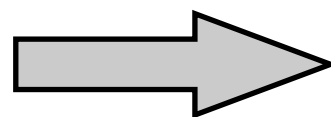


Positioning of Cryomodule

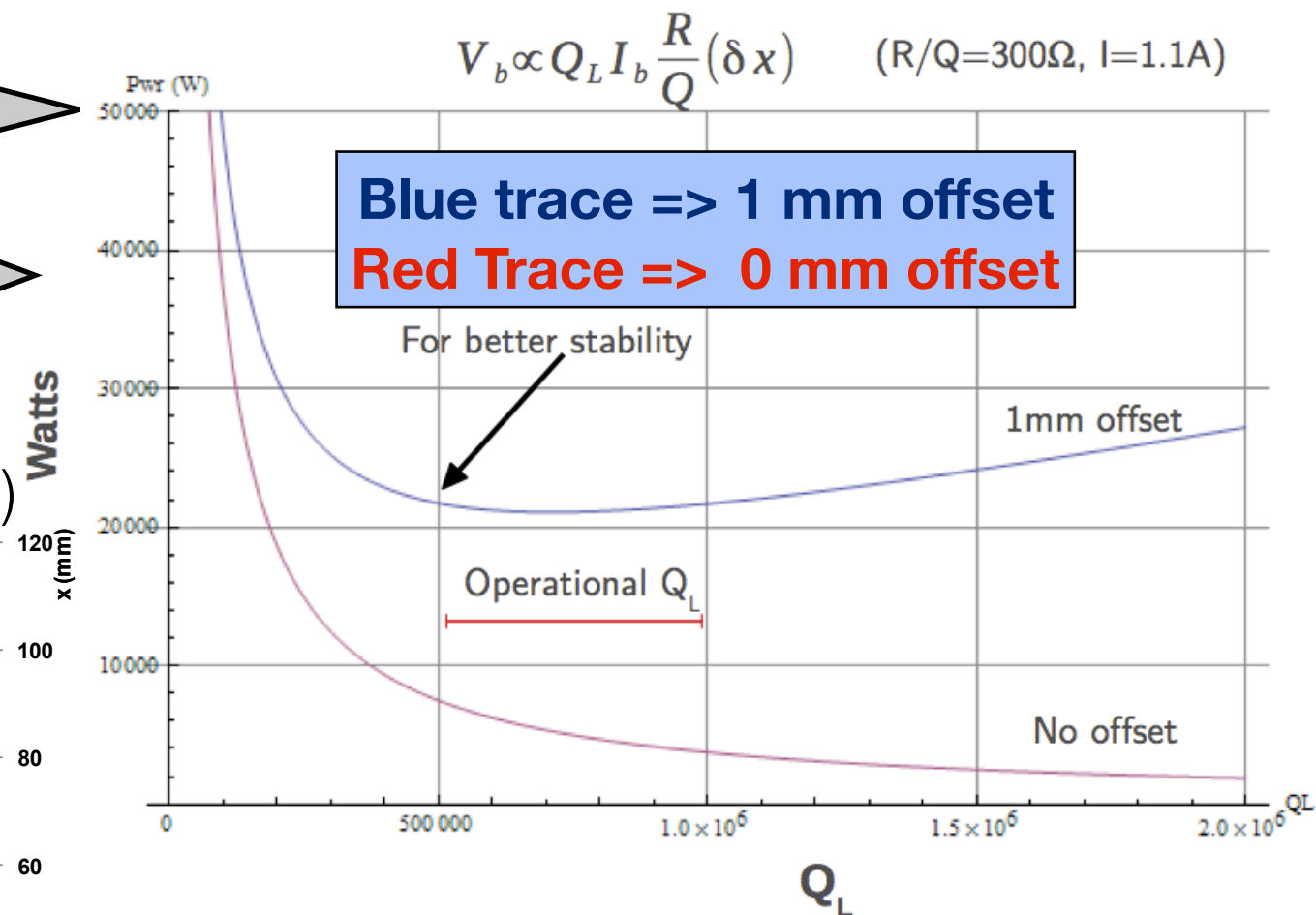
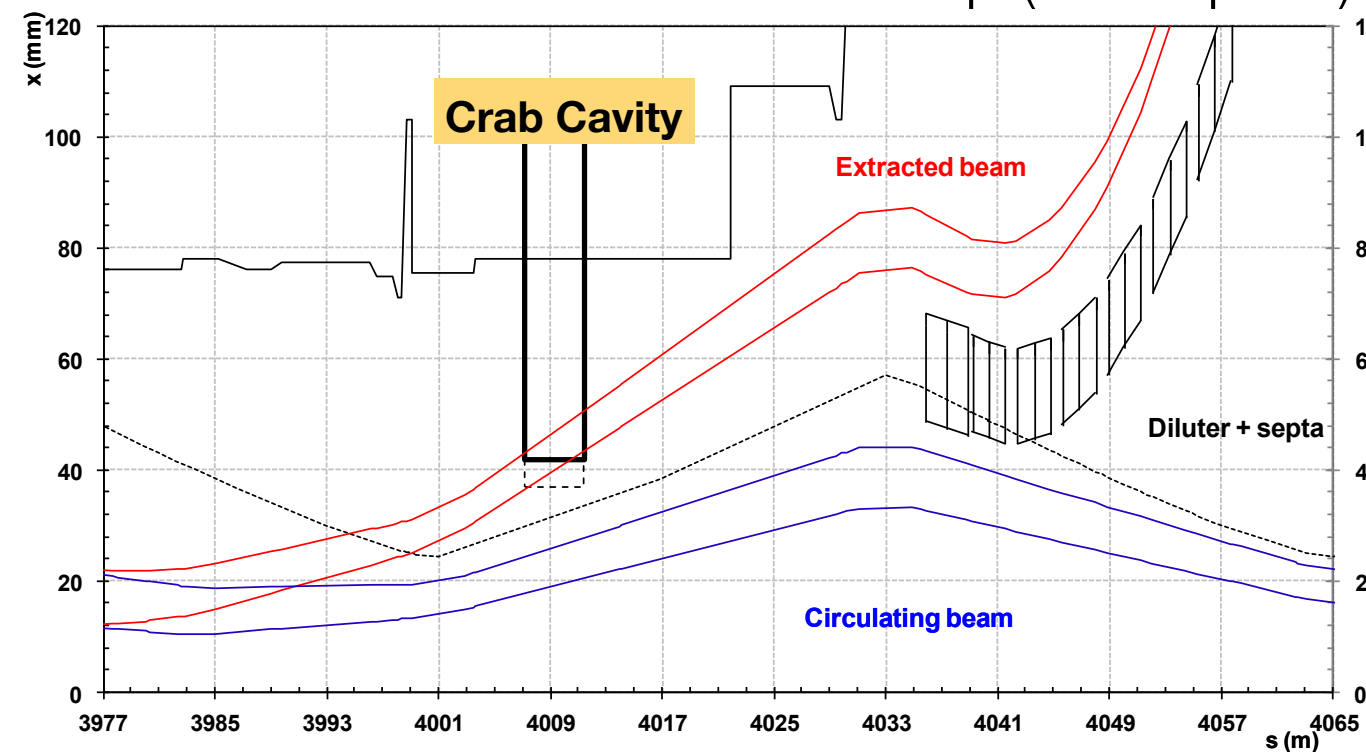
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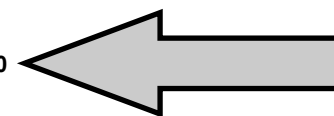
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SPS LSS4: LHC Extraction bump (Q20 optics)



Circulating beam is offset significantly wrt to nominal beam axis

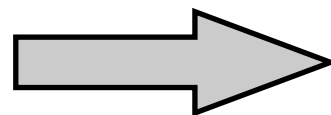


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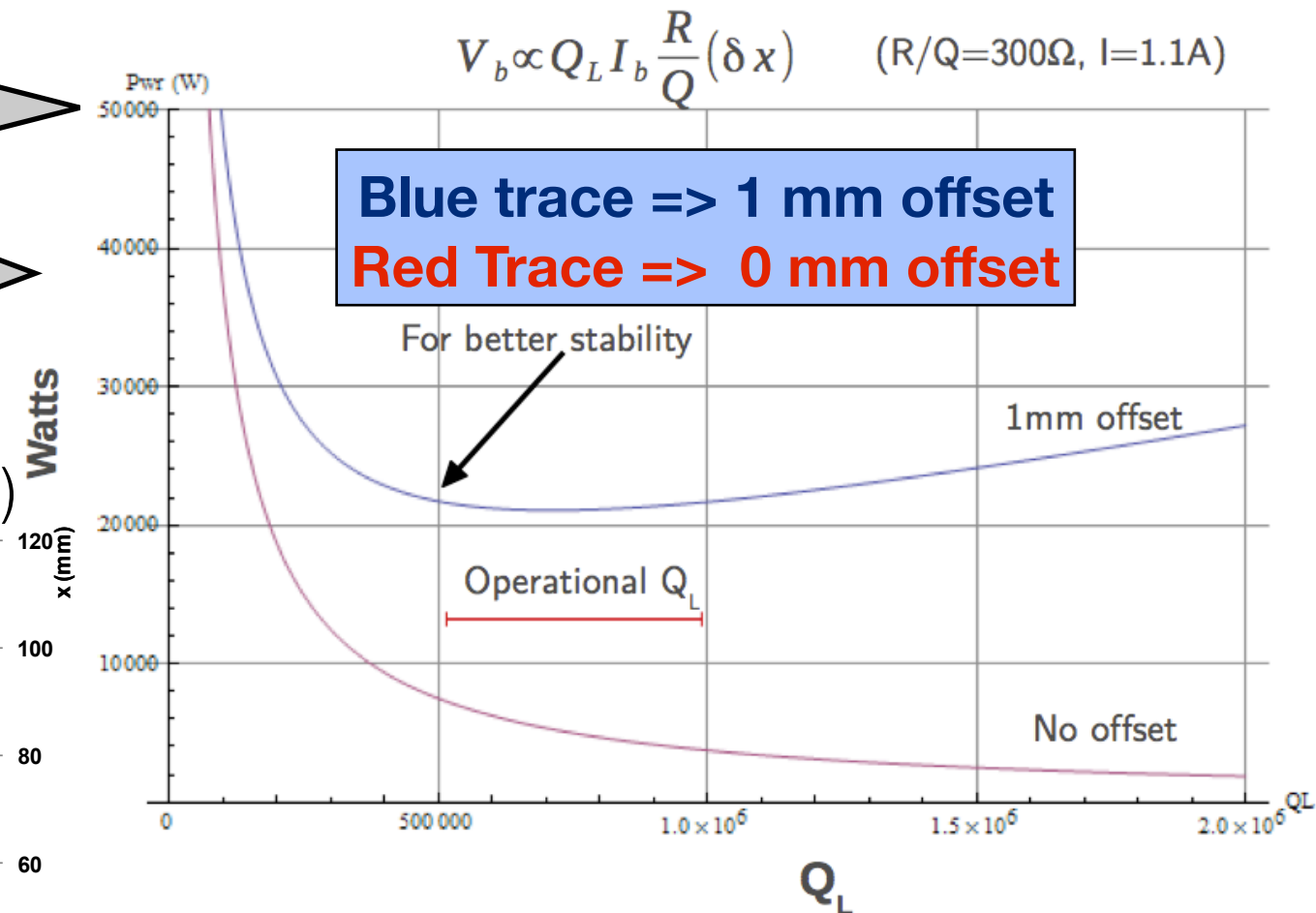
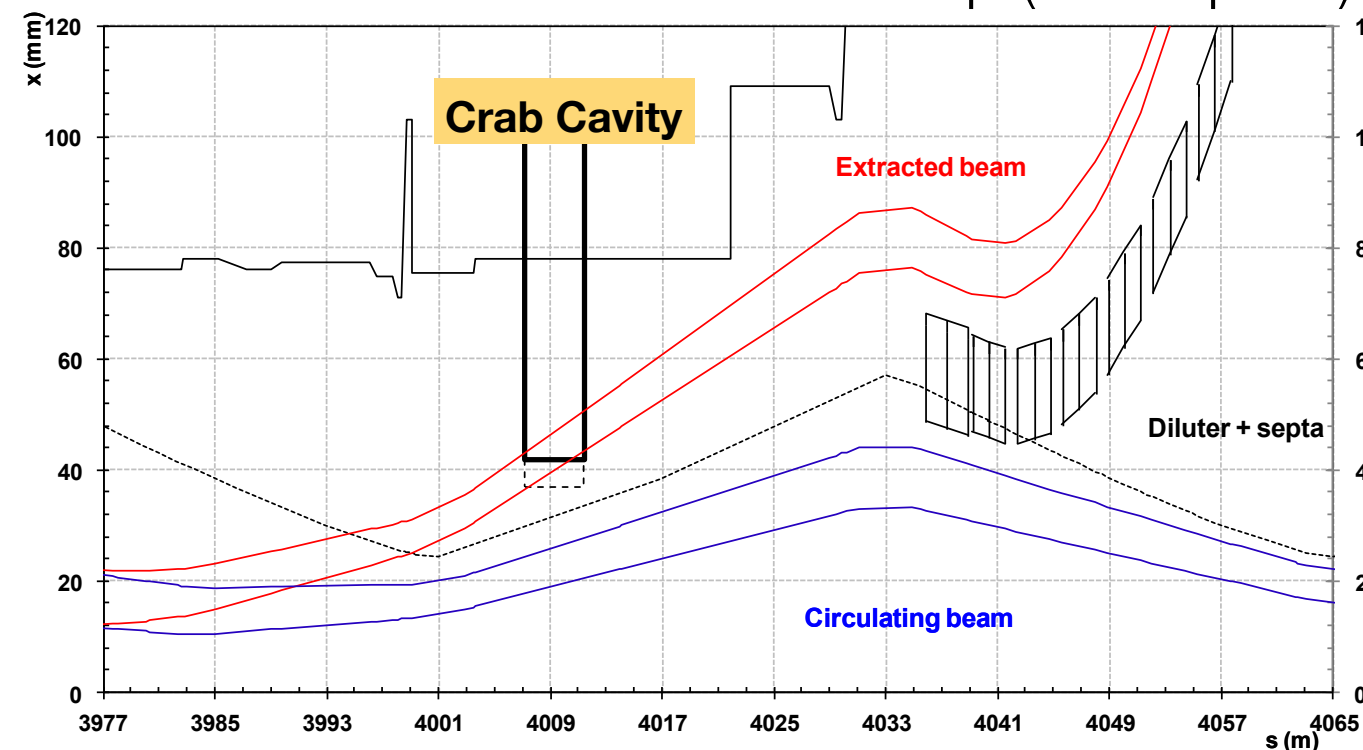
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SPS LSS4: LHC Extraction bump (Q20 optics)



Circulating beam is offset significantly wrt to nominal beam axis

**Position cavity axis wrt beam closed orbit position essential
=> active alignment + beam steering**

Positioning and Alignment

- **Reproducible positioning of cryomodule wrt nominal beam line**
 - Actual closed orbit position of beam can be measured (with bypass in)
 - Then cryomodule into beam position with calculated closed orbit offset
 - Cryomodule position tolerance = fraction of cavity alignment tolerance
 - Specifications assumed ~15% of transverse alignment tolerance
 - => support table transverse alignment tolerance for =100um**
 - Assumes rigid + accurate fixation of cryomodule to support table

Alignment requires active remote positioning of cryomodule/support table wrt beam closed orbit beam

Positioning and Alignment

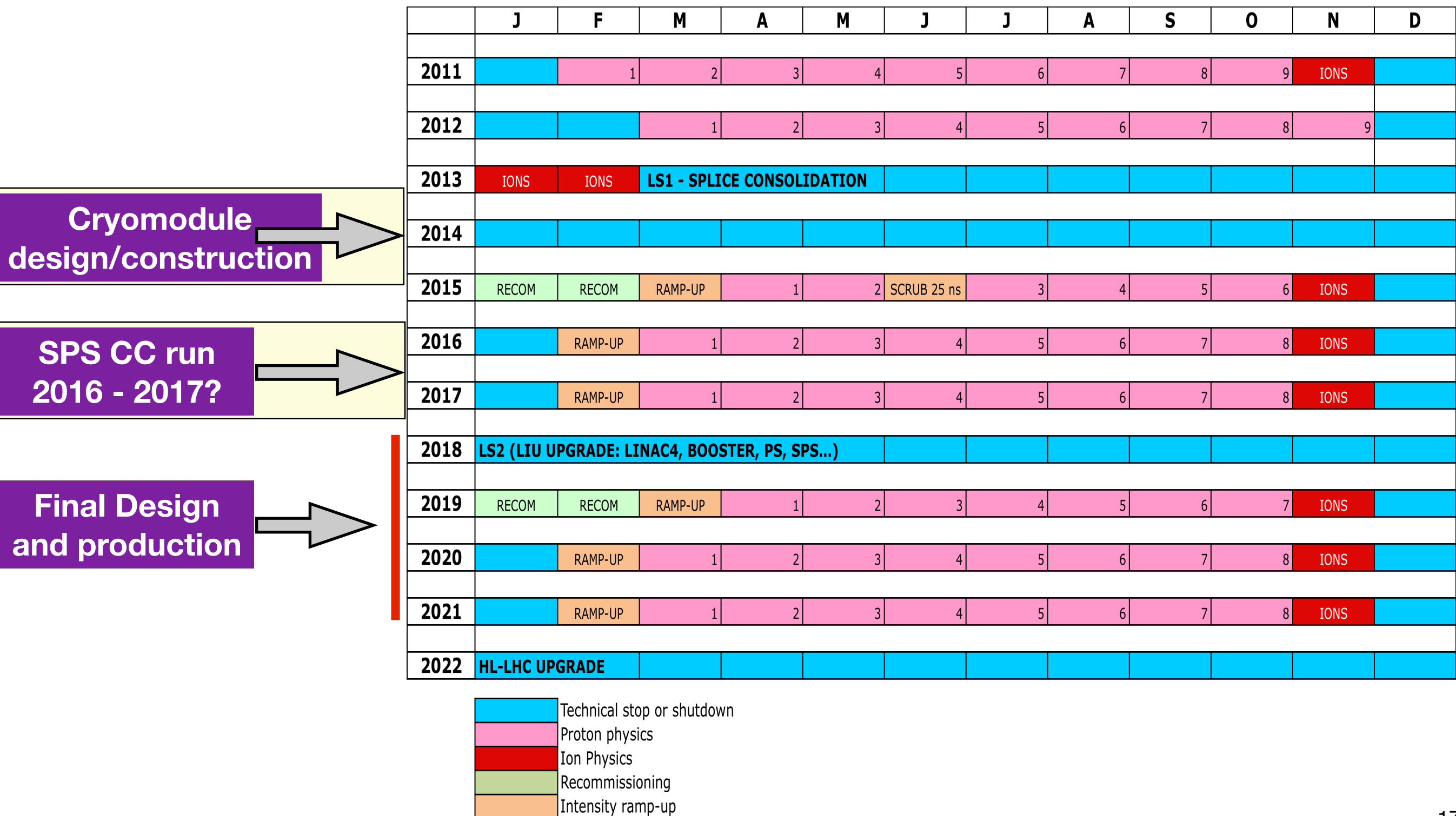
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- **Alignment of cavities within cryomodule**
- Need to understand expected relative mis-alignments due to installation and thermal cycling - what is expected
- Offers opportunity to understand how to resolve this for LHC scenario
 - potentially 3 independent cavities per cryomodule

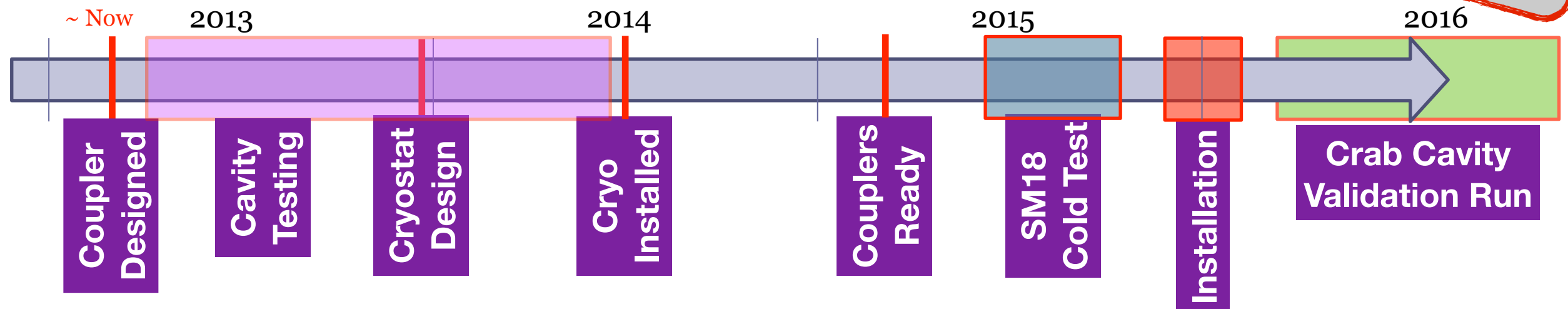
Constraints/implications on active alignment within cryostat needs discussion

Schedule - Simple Overview of SPS Crab Cavity Run



Schedule up to Installation in the SPS

Version based on
Dec 2012 planning



- Power coupler design completed: **Q1 of 2013**
- SM18 - Vertical tests of prototype cavities: **start Q2 of 2013**
- Cryostat design ready: **End of 2013**
- Cryogenic infrastructure installed in SPS LSS4 : **End of SPS LS1**
- Cabling infrastructure in SPS: **Q1 of 2014**
- Power Couplers available for cryostat: **Q1 of 2015**
- Cryomodule fully dressed: **Q2 of 2015**
- SM18 - Cryomodule fully tested: **Q3 of 2015**
- Cryomodule installed in SPS in December: **2015-2016 Christmas stop.**
- Crab Cavity validation MDs: **SPS Run 2016**

Conclusion

- **An integration envelope for the crab cavities in the SPS now exists**
 - Envelope contains cryomodule and its service connections
 - Definition of integration interfaces need to be defined
 - Needs detailed input to define integration + cryostat interfaces
- **Significant integration and space gains can be made if dummy beam pipe is not at the horizontal on the “SPS-inside” position**
- **Active positioning of the cryomodule wrt the beam center is essential**
 - Position to be done by control of the support table
- **Active alignment within the cryostat has to be discussed in detail**
 - But may help define solution for LHC installation